

Principal Investigator: Russell Stocker

**Pest Management Grants Final Report**

**Contract Number: 99-0217**

**Title: AERIAL RELEASE OF *TRICHOGRAMMA* TO CONTROL CODLING MOTH**

**Principal Investigator: Russell Stocker**

**Contract Organization: ARENA Pesticide Management  
3412 Laguna Avenue  
Davis, CA 95616**

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**Prepared for the California Department of Pesticide Regulation**

Principal Investigator: Russell Stocker

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Principal Investigator: Russell Stocker

## ACKNOWLEDGMENTS

### Key Personnel

Carolyn Pickel

Nick Mills, Ph.D.

Dave Ramos

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## ABSTRACT

*Cydia pomonella*, codling moth, is a serious exotic pest in walnuts and other crops in California. California produces virtually all the commercial walnuts in the United States on over 200,000 acres in 20 counties, with an annual crop value of over \$280 million. The Food Quality Protection Act (FQPA) will eliminate or reduce the use of commercial products, such as Guthion and similar organophosphates, that currently control codling moth populations. Therefore, alternative strategies, such as the use of *Trichogramma*, must be developed. Two major challenges to the implementation of *Trichogramma* in walnuts have been 1) how to place the parasitized eggs in the orchard canopy where the codling moths are found, and 2) how to do so economically.

This project has provided aerial release of *Trichogramma* parasitoids for a second year in conjunction with the Walnut Pest Management Alliance (PMA) Work Plan, whose personnel provided monitoring, timing, and the various control strategies described below. The Walnut PMA provided the parasitoids for the second generation releases and the principal investigator provided them for the third generation, reducing costs to growers who provided the orchard plots for testing.

The goal of the PMA Work Plan is to demonstrate and implement reduced-risk pest management systems in walnuts statewide and to communicate these strategies to the walnut industry. The use of *Trichogramma* to control codling moth is one component of these strategies. During the 2000 season, test plots were smaller than in 1999 to provide more replications and more uniform handling of each plot. The plots were managed with several strategies including: mating disruption and conventional pesticides, mating disruption and *Trichogramma*, mating disruption alone, conventional pesticides alone, and control plots where no pest control was implemented.

Unfortunately, there is no funding in the Walnut PMA Work Plan for the aerial release protocols, although there are funds, strategies and personnel for excellent plot identification, plot set-up, field monitoring, and data collection. The goal of this proposal was to provide a second year of aerial releases of *Trichogramma* to control codling moth. Some of the Walnut PMA sites used in 1999 were used again during the 2000 season. Although the plots were smaller, there were more replications within each plot and increased monitoring of the plots. Several plots used last year were involved in the BIOS program, which did not elect to use *Trichogramma* in the 2000 season.

Work by the principal investigator during the 1998-1999 and 1999-2000 growing seasons has demonstrated the technical success of metering and applying *Trichogramma* parasitized *Ephestia* eggs (parasitoids), in conjunction with an adhesive, from an aircraft to adhere the *Trichogramma* parasitoids to the foliage of walnut trees. Additionally, *Trichogramma* have been demonstrated to make an important contribution to an Integrated Pest Management (IPM) strategy for the control codling moth in walnuts. The issue of affordability remains a concern. Monitoring is costly and reduced-risk strategies for codling moth control continue to be more costly per acre than conventional methods. However, continued research is likely to demonstrate that a combined strategy of pheromone-based mating disruption in the first two generations followed by lower release rates of *Trichogramma* in the third generation could provide adequate control at a cost that is reasonably competitive with conventional methods of control.

Demonstration of a second year of successful control of codling moth using reduced-risk pest management strategies will provide important and useful data to the walnut industry. These positive results will improve the likelihood of adoption of reduced-risk strategies by the walnut industry.

## EXECUTIVE SUMMARY

*Cydia pomonella*, codling moth, is a serious exotic pest in walnuts and other crops in California. California produces virtually all the commercial walnuts in the United States on over 200,000 acres in 20 counties, with an annual crop value of over \$280 million. The Food Quality Protection Act will eliminate or reduce the use of commercial products such as Guthion and similar organophosphates that currently control codling moth populations. Therefore, alternative strategies, such as the use of *Trichogramma*, must be developed. Two major challenges to the implementation of *Trichogramma* in walnuts have been 1) how to place the parasitized eggs in the orchard canopy where the codling moths are found, and 2) how to do so economically. Previous work has demonstrated the technical feasibility of metering and applying *Trichogramma* parasitized *Ephestia* eggs (parasitoids) from an aircraft, in conjunction with an adhesive, to adhere *Trichogramma* parasitoids to the foliage of walnut trees. *Trichogramma* also have been demonstrated to provide a measure of control of codling moth in walnuts, which is likely to be improved when combined with other Integrated Pest Management (IPM) strategies, such as pheromone-based mating disruption. This project has provided the aerial release of *Trichogramma* parasitoids, under controlled and monitored conditions, in conjunction with the Pest Management Alliance (PMA) Work Plan for California Walnuts, to answer these questions.

In cooperation with the Walnut PMA, 44 timed releases of *Trichogramma* parasitoids were made over 31.8 acres of walnuts located in six orchards and involving growers in five counties. The strategies used during the 2000 season for codling moth control were: 1) mating disruption alone (using Isomate or Checkmate), 2) mating disruption and Lorsban, 3) mating disruption and *Trichogramma*, and 4) grower standard, all of which were compared to control plots where no codling moth control measures were implemented.

Monitoring of the codling moth population is an important component in the success of these reduced-risk strategies. Without accurate monitoring, implementation of the reduced-risk strategy can be ill-timed and subsequent control rates are inadequate for the method to be acceptable on a commercial scale. The Walnut PMA was responsible for the monitoring protocols throughout the season and determined the pheromone and/or *Trichogramma* release dates. A second component of these reduced risk strategies is the ability to apply the strategy once monitoring has determined the optimum timing of the method. For a second year, there were no problems with the *Trichogramma* release system, which allows for rapid and accurate (both in location and rate) releases of the parasitoids onto the walnut canopy.

For these reduced-risk strategies to be adopted commercially, they must be affordable. Monitoring is costly and reduced-risk strategies presently are more costly per acre than conventional pesticides. In this second year of trials, reduced-risk practices remained more costly than conventional pesticides. However, it appears that the use of mating disruption during the first and second generations, followed by *Trichogramma* in the third generation may provide the best control strategy. As these strategies refined, and production of the parasitoids and pheromones are increased, costs will be reduced.

Finally, together with the Walnut PMA, the principal investigator has demonstrated the aerial release of *Trichogramma* to be an effective component of reduced-risk strategies to control codling moth in walnuts. The results of these investigations have been disseminated to the walnut industry through various publications and meetings where the results of the program were well received.

## REPORT

### A. Introduction

Codling moth, *Cydia pomonella*, is a major exotic pest of walnuts, apples and pears in California and elsewhere in the United States. It was introduced from Eurasia and has spread rapidly, becoming a major problem in three quarters of the California counties where walnuts are grown. California produces virtually all the commercially produced walnuts in the United States with over 205,000 acres in 20 counties dedicated to walnut production. Annual crop value is \$280 million, placing walnuts among the top five in California's fruit and nut crops.<sup>1,2,3</sup> Pheromone-based mating disruption is one Integrated Pest Management (IPM) strategy for codling moth control<sup>4,5,6</sup> that has worked well in apples and pears. The pheromone dispensers that are so successful in apples and pears are placed in the orchards by hand. Unfortunately, pheromones as a stand-alone strategy have not been as successful in walnuts for several reasons. First, there is no acceptable placement method that is fast and cost effective in the much larger trees and over the larger acreages. Second, the growing season for walnuts is longer, which necessitates additional applications of the pheromone material to effect adequate control, resulting in higher and probably prohibitive costs.

Current practices for the release of *Trichogramma* involve the refrigerated shipment of pupae, ready to emerge as adults, inside parasitized grain moth eggs, known as parasitoids, which are glued to perforated cards. The cards are broken into squares on-site and distributed by hand in orchards by stapling the squares to leaves or by incubating the parasitized eggs in paper wedge cups, which are then set out after the adults emerge. Both the card and cup practices are highly labor intensive and not feasible on a commercial scale in walnuts because the trees are so large and cover so many acres.

Earlier work conducted by Nick Mills and Carolyn Pickel has demonstrated that *Trichogramma* do not perform adequately in walnuts as a stand-alone method during the first generation, resulting in higher than acceptable canopy counts in the second and third generations. During the 1999 season, "soft pesticides" such as Confirm were used during the first generation followed by *Trichogramma* in the second and third generations. Studies in apples and pears have shown the potential success of mating disruption with pheromones and, in fact, approximately 80% of pear orchards in California now use mating disruption, primarily due to the loss of commercial organophosphate materials.

The combination of mating disruption in the first generation, using Isomate or Checkmate, followed by *Trichogramma* in the second and third generations, was thought by N. Mills and C. Pickel to be a promising scenario, particularly when the *Trichogramma* could be released by air (i.e., quickly and in the canopy).

Previous work by the principal investigator and the Walnut PMA team has demonstrated the feasibility of releasing the *Trichogramma* parasitoids at a predetermined rate by air, in conjunction with an adhesive, to facilitate placement of the parasitoids in the upper canopy where the codling moths are found. The primary goal of this proposal was to provide a second year of demonstrations, increasing confidence in the release technique and providing additional data on how well the release of *Trichogramma* coordinates with mating disruption protocols to provide a cost effective reduced-risk strategy for the control of codling moth in walnuts. Secondary goals were to provide a cost comparison of this strategy to the Grower Standard and to communicate the results of these studies to the walnut industry.

## Project Objectives

1. Provide the aerial release of *Trichogramma* parasitoids and demonstrate the success of the system at controlling codling moth in walnuts during a subsequent growing season.

The goal of the Walnut PMA Work Plan is to demonstrate and implement reduced-risk pest management programs in walnuts statewide and to communicate these strategies to the walnut industry. The use of *Trichogramma* to control codling moth is one of these strategies. Previous release protocols have been prohibitive because they were labor intensive and slow, and, therefore, both costly and less effective than conventional control methods. The aerial release strategy is comparably priced and very fast, which has increased the potential for adoption of this method of control. This proposal provided the technical expertise to place the *Trichogramma* parasitized *Ephestia* eggs (parasitoids) in the upper canopy of the walnut trees, where the codling moths are present, in order to effect control of this significant pest without the use of conventional pesticides such as organophosphates.

2. Provide a comparison of costs between these strategies and Grower Standard.
3. Communicate the success of this strategy to the industry

## B. Results

1. Provide aerial release of *Trichogramma* parasitoids, in conjunction with an adhesive, to walnut orchards participating in the Walnut PMA .

In cooperation with the Walnut PMA and based on the protocols described below, the investigator made 44 timed releases of *Trichogramma* parasitoids over 31.8 acres of walnuts located in six orchards belonging to growers in five counties (Table 1). The Walnut PMA teams have provided canopy count data from the second and third codling moth generations, which is used as an indicator of codling moth activity, as well as harvest data (all provided in Table 2).

Drawing on previous experience of the Walnut PMA team and the recommendation of Steven Welter of UC Berkeley, who is a specialist in pheromones and a new participant for 2000, the pheromone: *Trichogramma* protocol was implemented for the 2000 season by Carolyn Pickel, Walnut PMA Field Team Coordinator. The specific test plot protocols for the 2000 season included:

Isomate/Lorsban - Isomate, a pheromone product in a dispensing apparatus, is used in the first generation, or until the dispensers are expended. Lorsban, an organophosphate, is used in second and third generations.

Isomate/Trichogramma - Isomate is used in the first generation as above. *Trichogramma* are used in the second and third generations.

Isomate - Isomate alone is used in all generations.

Checkmate - Checkmate (another brand of pheromone) is used in all generations.

Checkmate/Lorsban - Checkmate is used in the first generation, followed by Lorsban in the second and third generations.

Grower Standard - Growers use whatever method(s) of codling moth control they have used in the past. These methods include conventional organophosphate and carbamate pesticides.

Control - No pest control methods of any type are used.



As described in the original proposal, pheromone-based mating disruption with Isomate or Checkmate was used during the first codling moth generation, followed by appropriately timed aerial releases of *Trichogramma* during the second and third codling moth generations in selected plots. The timing of these releases was coordinated by Carolyn Pickel, based on data provided by the field monitoring scouts. Table 1 provides details of the release dates in each orchard.

Data from all treatment groups from canopy counts in the second (2<sup>nd</sup>) and third (3<sup>rd</sup>) generations, as well as harvest (H), are shown in Table 2. Canopy counts for the first generation (when mating disruption was the only control used) are also available, but do not apply to the second and third generations treated with *Trichogramma*. The figures from the second and third generations are useful in that they provide researchers and growers an estimate of the data expected when final counts are tallied during harvest, canopy counts being approximately half the damage found at harvest/nut crack.

Preliminary results during the growing season appeared most encouraging for the Isomate/*Trichogramma* protocol and, overall, this strategy has provided reasonable control compared to the Grower Standard at harvest (Table 2). Damage in most plots treated with Isomate (or Checkmate) and *Trichogramma* was 0 - 1.2% compared to 0 - 0.8% in the Grower Standard plots and 0 - 3.5% in the control plots. The exception, when one examines the data, is the Deseret Farms (D-10) site. Regardless of treatment regimen, this site exhibited substantial damage compared to the other orchards participating in the trial.

The consensus among the research team is that the Deseret (D-10) plot was negatively impacted by several factors. First, this orchard is comprised of particularly large trees in comparison to the other test plots, making canopy counts difficult unless a tree squirrel is used to collect samples from the upper canopy, which it was not. Second, because of the larger canopy, extra samples should have been taken in proportion to the canopy's larger size/volume. This also was not done. Without these extra monitoring tasks, researchers had a false impression of low pest pressure when the opposite was actually the case. Third, these plots likely experienced pest carry over from 1999 when there was an early season breakdown of the pheromone/paraffin emulsion, followed by a high worm count at harvest. This could result in a "hot spot" of high codling moth pressure carrying over to the 2000 season. Finally, the Walnut PMA team determined that there were plot design and monitoring difficulties at the Deseret (D-10) site. Specifically, codling moth traps used for monitoring purposes in the Grower Standard plots adjacent to the Isomate/*Trichogramma* plots and pheromone dispensers for codling moth control protocols in the Isomate/*Trichogramma* plots had been placed too close together. This caused what is known in the industry as "trap shut down". In effect, the area of the orchard where the monitoring traps were placed was so permeated with pheromone material that the traps were virtually useless. The traps did not attract the codling moths that were present, giving the monitoring team the impression that there was little or no pest pressure when, in actuality, pests were present in significant numbers.

In spite of the difficulties experienced at the Deseret Farms (D-10) site, this additional year of releases has solidly reinforced the technical feasibility of placing the *Trichogramma* parasitoids in the canopy of the walnut orchards. It also has demonstrated the combination of pheromone-based mating disruption in the first generation, followed by *Trichogramma* in second and third generations, can provide a level of codling moth control that is acceptable to the industry.

## 2. Provide cost comparisons

An additional goal of this proposal is to demonstrate the cost effectiveness of the use of *Trichogramma* to control codling moth. Table 3 provides cost comparisons, by grower/orchard,

of the Grower Standard protocol to the Walnut PMA protocol using mating disruption in the first generation followed by *Trichogramma* releases in the second and third generations.

It is clear from Table 3 that the Walnut PMA protocol is more expensive in all but one case. However, several factors should improve these figures over time. First, as the strategy becomes adopted by the industry, the supply of parasitoids should increase and more/improved pheromones should become available; both factors will increase competition and production, thereby reducing costs. Second, better monitoring and additional experience should result in lower numbers of *Trichogramma* parasitoids needing to be released per acre. The current strategy involves "innundative" releases of 200,000 parasitoids/acre. This may not be necessary except in the heaviest pest pressure situations. And, third, it may be possible to utilize pheromone-based mating disruption alone in the first AND second generations (because the material lasts ~120 days), releasing *Trichogramma* only during the third generation. This scenario could significantly reduce costs to the grower and further research will be required to investigate this possibility.

### 3. Communicate the success of this strategy to the industry

This strategy has been communicated at two additional forums by the principal investigators and statewide by farm advisors and the members of the Walnut PMA (Table 4). A third event is scheduled for March, 2001.

The beneficial insect release system has been presented by the principal investigator at the Community Alliance with Family Farmers Field Day, March 9, 2000, and (in place of N. Mills) at the Walnut Pest Management Alliance and San Joaquin BIOS Project Statewide Field Meeting, August 30, 2000. The principal investigator also has attended the Walnut PMA meeting December 1, 2000 at the UC Cooperative Extension Office, Stockton, CA and has been invited to participate in the conference "Partnerships for Sustaining California Agriculture: Profit, Environment and Community" which is scheduled for March 27-28, 2001 at the Heidrick Agricultural History Center, Woodland, CA and will highlight innovations in agricultural production and research --- practices that are profitable as well as environmentally friendly.

In all circumstances to date, the program has been well received. In addition to these personal presentations by the principal investigator, this strategy has been communicated statewide by farm advisors and the members of the Walnut PMA.

## C. DISCUSSION

The aerial release of *Trichogramma* parasitoids from an aircraft in conjunction with an adhesive has been successfully accomplished. The use of *Trichogramma* parasitoids together with pheromone-base mating disruption products for the control of codling moth also has been demonstrated to provide a good level of codling moth control in comparison to the Grower Standard (conventional pesticides), although the method is generally more expensive.

What should be noted is that orchards that exhibited lower pest pressure used less chemical control products in the Grower Standard plots, resulting in lower costs. This is clearly demonstrated in the Deseret (D-10) plot. Because the grower believed (in error) there was low pest pressure, minimal conventional materials were used and costs were very low. Unfortunately, due to the monitoring problems noted above, this plot experienced 4.6% damage in contrast to the other Grower Standard plots that all reported damage rates of less than 1%. This experience underscores the need for excellent orchard-specific monitoring strategies.

With wider adoption of this reduced-risk strategy by the walnut industry and continued use, it is possible that over a number of years codling moth (and other pest) pressure will be reduced.

This is particularly true because the use of current chemical materials (organophosphates and carbamates) eliminates beneficial insects and results in mite infestations, for example, that require additional pesticide applications. The pheromone/*Trichogramma* strategy does not eliminate the beneficial insects, thus there is no need for the additional pesticides. Finally, as pest pressure is reduced, fewer *Trichogramma* per release and fewer releases during the third generation (both of which will release costs) may be needed for acceptable control of codling moth.

#### D. SUMMARY and CONCLUSIONS

The timetable for this project has been met and the expenses are within the budget proposed. There have been no significant problems with the release system and the principal investigator has not been prevented from meeting the objectives of the proposal or completing any of the specified tasks.

This project is demonstrating successful alternatives to highly toxic pesticides, which reduces use of and human exposure to those pesticides while protecting surface and ground water quality. The project has experienced some problems related to human error (such as the trap placements described for the Deseret D-10 plot), which underscore the need for: 1) strong communication between growers and researchers and 2) excellent monitoring strategies and protocols for this strategy to be successful and subsequently accepted by the industry. In addition, this project is a cooperative and collaborative effort between growers, the Walnut PMA, and industry that uses a systems approach to the solution of a significant problem in the walnut industry.

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**TABLE 1** *Trichogramma* Release Dates during 2000, per Walnut PMA

Grower Orchard	Total Acres	County	Release Dates	Release Dates
			Second Generation	Third Generation
Barton Farms	5.0	San Joaquin	6/28/00 7/4, 13, 20/00	none*
Deseret Farms	5.3	Butte	6/17, 24/00 7/2, 8/00	8/2, 8, 15, 20/00
Deseret Farms (D-10)	5.0	Yuba	6/15, 22, 29/00 7/6/00	7/27/00 8/4, 10, 17/00
Chappe	6.0	San Joaquin	6/28/00 7/4, 13, 20/00	8/4, 11, 18, 25/00
Campos Brothers Farms	6.0	Fresno	6/13, 19, 26/00 7/3/00	7/24, 30/00 8/7, 14/00
Pacific Farms	4.5	Tehama	6/17, 24/00 7/2, 8/00	7/24/00 8/2, 8, 15/00

\*Barton Farms inadvertently sprayed the Walnut PMA plots with Asana while treating the remainder of their orchard. This put an end to the use of *Trichogramma* for the season. Asana has residual action that would be detrimental to the *Trichogramma* so there was no point in releasing them.

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**TABLE 2 Canopy Counts and Harvest Data for 2000**

Percent damage in second generation (left column, 2<sup>nd</sup>), third generation (center column, 3<sup>rd</sup>) and at harvest (right column, H) for each treatment regimen within each test orchard

Treatment	Grower Standard			Isomate/ Lorsban			Isomate / Trichogramma			Isomate			Checkmate			Checkmate/ Lorsban			Control		
	2 <sup>nd</sup>	3 <sup>rd</sup>	H	2 <sup>nd</sup>	3 <sup>rd</sup>	H	2 <sup>nd</sup>	3 <sup>rd</sup>	H	2 <sup>nd</sup>	3 <sup>rd</sup>	H	2 <sup>nd</sup>	3 <sup>rd</sup>	H	2 <sup>nd</sup>	3 <sup>rd</sup>	H	2 <sup>nd</sup>	3 <sup>rd</sup>	H
Grower/Orchard																					
Barton Farms*	0	n/a	0	0	n/a	0.5	0	n/a	0.7	0.2	n/a	0.5							0.2	n/a	3.5
Deseret Farms	0.8	0.4	0.8	0	0.4	0.2	0.4	1.4	1.2	0.8	0.4	2.6							1.4	2.4	3.2
Deseret Farms (D-10)	1.8	6.6	4.6	0	0	0.4	2.8	1	6.2	3	2.8	3	0	0.8	1.2	0.4	0	1.2	1	3.2	2.5
Chappe	0	n/a	0.1	0	n/a	0	0	n/a	0.7	0	n/a	0.5							4	n/a	3.5
Campos Brothers Farms	0	n/a	0	0	n/a	0	0	n/a	0	0	n/a	0							0	n/a	0
Pacific Farms	0	0	0.6	0.4	0	1	0	0	0	0	0.2	0							0.4	0/6	0.4

\*Barton Farms inadvertently sprayed the Walnut PMA plots with Asana while treating the remainder of their orchard. This put an end to the use of *Trichogramma* for the season. Asana has residual action that would be detrimental to the *Trichogramma*, so there was no point in releasing them.

**TABLE 3      Comparison of Cost per Acre in 2000**

Estimates of costs of Grower Standard treatments, using retail costs of materials and application expenses, compared to the Walnut PMA protocol using Isomate (pheromone-based mating disruption) during the first generation and *Trichogramma* aerial releases during the second and third generations.

Grower/ Orchard	Cost per Acre ( \$ )	
	Grower Standard	PMA Protocol
Barton Farms*	298.88	214.00
Deseret Farms	51.25	298.88
Deseret Farms (D-10)	70.00	298.88
Chappe	103.64	298.88
Campos Brothers Farms	228.46	298.88
Pacific Farms	59.62	298.88

**TABLE 4      Presentations**

<b>Date</b>	<b>Location</b>	<b>Audience / Forum</b>
March 9, 1999	Yuba City, CA	Walnut Pest Management Alliance Regional Team Meeting Slide presentation and equipment
March 10, 1999	Modesto, CA	Walnut Pest Management Alliance Regional Team Meeting Slide presentation and equipment
March 11, 1999	Parlier, CA	Walnut Pest Management Alliance Regional Team Meeting Slide presentation and equipment
April 23, 1999	Ripon, CA	Community Alliance with Family Farmers (CAFF) Farm Tour Presentation on aerial <i>Trichogramma</i> releases Equipment demonstration
June, 22, 1999	Hanford, CA	Walnut Pest Management Alliance Regional Field Meeting Presentation using release equipment
June 22, 1999	Sacramento, CA	Featured article on KCRA - TV's Morning Show
August 16, 1999	Sacramento, CA and vicinity	Featured in an article in the Sacramento Bee and other smaller local area newspapers "Pitting good bugs against bad" by Edie Lau
August 19, 1999	Chico, CA	Walnut Pest Management Alliance Regional Field Meeting Presentation using release equipment and Demonstration of aerial release
November 3, 1999	Woodland, CA	CAPCA Meeting Slide presentation
March 9, 2000	Winters, CA	Community Alliance with Family Farmers (CAFF) Field Day "Managing Codling Moth in Walnuts without Organophosphates" Presentation on aerial releases; aerial release demonstration
August 30, 2000	Farmington, CA	Walnut Pest Management Alliance and San Joaquin BIOS Project Statewide Field Meeting "Trichogramma Releases: Successes and Limitations" Presentation made in place of N. Mills, Ph.D.
December 1, 2000	Stockton, CA	Walnut Pest Management Alliance Meeting UC Cooperative Extension Office
March 27-28, 2001	Woodland, CA	Partnerships for Sustaining California Agriculture: Profit, Environment and Community Presentation of workshop - orchard session